RESEARCH ARTICLE OPEN ACCESS

Analysis of Mtbe as an Oxygenate Additive to Gasoline

C.AnishRaman[1],Dr.K.Varatharajan[2],P.Abinesh[3],Dr.N.Venkatachalapathi[4]
[1] Dept. of Mechanical Engineering, Velammal Engineering College, Chennai, Tamil Nadu,India
[2] Dept. of Mechanical Engineering, Velammal Engineering College, Chennai, Tamil Nadu,India
[3] Dept. of Mechanical Engineering, Velammal Engineering College, Chennai, Tamil Nadu,India
[4]Dept. of Mechanical Engineering, Velammal Engineering College, Chennai, Tamil Nadu,India

ABSTRACT
One of the major drawbacks of IC engines is low efficiency and pollution resulting from incomplete combustion. In order to improve the emission properties and performance an oxygenated additive MTBE (Methyl *tertiary* butyl ether), is blended with gasoline. A four cylinder, 1817 cc engine was used for analysing both emission and performance characteristics. Tests were carried out with 100% pure gasoline and MTBE – blended gasoline (M5, M10). The BSFC and BTE of MTBE blended gasoline were observed to increase when compared to pure gasoline. Significant reduction in HC and CO emissions were observed with MTBE blended gasoline; however, CO_2 and NO_X emissions were increased.
Keywords: SI Engine, CO_2, Emission, HC, MTBE, Oxygenate Additive.

I. INTRODUCTION

Additives are added to gasoline for various reasons like octane rating improvement , inhibition of corrosion, use as an oxygenate and antioxidants. Having an oxygen molecule MTBE is used as an oxygenate agent. Oxygenated additives are added to gasoline to obtain more efficient combustion of fuel. These usually have oxygen content, aiding the burning of fuel. Here Methyl tertiary butyl ether (MTBE), a colorless liquid at room temperature is used as an oxygenate additive.

Lennox Siwale et al. [1] studied the combustion and emission characteristics of dual alcohol (n-butanol and methanol) blended gasoline and was compared with that of single alcohol (methanol) blended gasoline, n-butanol was used to solve the problems in fuel delivery system on using methanol blended gasoline. Mohsen et al. [2] decreased the emission of pollutants especially CO when ethanol was blended with gasoline. Shen et al. [3] 3-Hydroxybutyrate methyl ester was blended with gasoline and its performance was similar or superior to that of ethanol blended gasoline in terms of oxygen content, dynamic viscosity, flash point and boiling point. Soheil et al. [4] accomplished improvement in physicochemical properties and also increased the octane number and Reid vapor pressure by blending Methyl Tertiary Butyl Ether (MTBE), Methanol, Tertiary butyl alcohol (TBA), and Tertiary amyl alcohol (TAA) blend with gasoline. G.A. Westphal et al.[5] reduced the Toxicity and BTEX emissions by using MTBE and ETBE blended gasoline. Sara Safari Kish et al.[6] blended Amino functionalized Carbon Nanotube with gasoline to achieve increment in octane number. Dale Turner et al.[7] observed that the changes in impact of blending bio-ethanol with gasoline on fuel efficiency and emission to followed a certain pattern with the blending ratio .The performance and emission of bio-ethanol blended with gasoline was measured at various blend ratios and the impact changed with certain pattern.

The effect of blending methanol with gasoline on engine performance and emission was studied using a 4 cylinder engine[10]. Renato et al.[9] improved engine performance and acceleration by blending gasoline with ethers such as TAEE, di-TAE,MTBE with gasoline. Having an oxygen atom in their molecule these needed a lower air fuel ratio.

Methyl t-butyl ether (MTBE) was produced using reaction between methanol and iso-butane using MFI –type zeolite catalyst [8].The emission characteristics of pure and high alcohol blended with gasoline was studied. Gasoline was blended with different alcohols methanol, ethanol, propanol , butanol, pentanol. A single cylinder engine was used for the testing purposes.[10] Analysis of catalytic conversion efficiencies and THC,CO,NO_X emissions of ethanol blended gasoline were measured[11] .

Many oxygenate additives such as ethanol, ETBE and MTBE and non oxygenate additives such as isooctane and toluene were blended with gasoline at different volumetric ratios. Their octane number and Reid vapour pressure was estimated. It was observed that addition of MTBE and ethanol resulted in the increase of Reid vapour pressure[12].The effect of using ethanol and MTBE was compared in an EFI gasoline engine. The regulated and unregulated exhaust emissions before and after the use of catalytic converter was measured[13].The spray properties of gasoline-ethanol were studied at various blending ratios and was examined with swirl-type injector sprays [14].

II. ABOUT GASOLINE

Gasoline is a saturated hydrocarbon having a chemical formulae(C_8H_{18},molecular mass 114).It is a volatile, flammable liquid at room temperature and has a density of 0.71 kg/l. Gasoline is primarily used as a fuel in SI engine due to its high calorific value (42,000 kJ/kg). Gasoline is also used as a thinner because of high volatility.

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

The motor octane number of gasoline is 92, while the research octane number is 97. A higher octane number aids in increasing the compression ratio and ultimately hiking the output power. Octane number can be boosted by adding oxygenated additives to gasoline.

III. PROPERTIES OF MTBE

CHEMICAL FORMULAE	$C_5H_{12}O$
DENSITY(60° F)	0.744(gm/cm^3)
MOLECULAR MASS	88.15
OXYGEN CONTENT	18.15%
FLASH POINT (° F)	14° F
MELTING PONT	-164° F
BOILING POINT	131° F
VISCOSITY (CENTIPOISE (60° F))	0.35
RESERCH OCTANE NUMBER	116
MOTOR OCTANE NUMBER	101
REID VAPOR PRESSURE	7.8(psi)
AIR FOR STOCHIOMETRIC MIXTURE (60° F)	11.8(Btu/lb)
AUTOIGNITION TEMPERATURE	815(° F)
LOWER HEATING VALUE	35.1(35.1 MJ/kg)
STOCHIOMETRIC AIR FUEL –RATIO	6.4

IV. EXPERIMENTAL SETUP

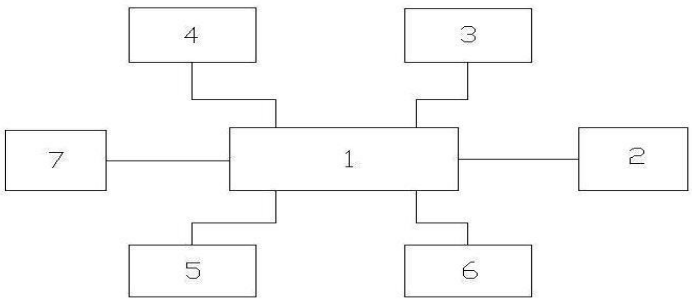

Figure1

A 1817 cc Hindustan Motors Ambassador Avigo 1800 ISZ MPFI petrol engine was used for testing purposes. It had a bore diameter of 84mm and a stroke of 82mm.It is a 4 cylinder engine with maximum power 75bhp@5000RPM and maximum torque 130NM@3000RPM.The compression ratio was 8.5.AVL Di-gas analyser was used for exhaust gas analysis. A constant load of 10 kgf was given to the system .A monometer was used for measuring the inlet air flow. An eddy current dynamometer was used for torque measurement. A burette was fixed with a engine for the measurement of fuel consumption.

1. Engine
2. Load Indicator
3. AVL Di-Gas Analyser
4. Eddy Current Dynamometer
5. Monometer for Measuring Air Inlet
6. Fuel Tank attached with a Burette
7. Exhaust Gas Pipe

V. ENGINE SPECIFICATION

MANUFACTURER	AMBASSADOR
TYPE	MPFI
CAPACITY	1817cc
NO. OF CYLINDERS	4
BORE x STROKE	84mm x 82mm
MAXIMUM POWER	75bhp@5000RPM
MAXIMUM TORQUE	130NM@3000RPM
COMPRESSION RATIO	8.5:1
COOLIN G SYSTEM	WATER COOLED

VI. EXPERIMENTAL TESTING

Testing was done on pure gasoline, 5%MTBE blend gasoline (M5),10% MTBE blend gasoline(M10) at distinct engine speeds 800 rpm,1200 rpm, 1600 rpm,2000 rpm,2400 rpm. For performance analysis the Brake Specific Fuel Consumption(BSFC),Brake Thermal Efficiency(BTE) were calculated for pure gasoline,M5,M10 in the selected speeds. The performance characteristics was obtained by plotting BSFC and BTE versus speed. A flue gas analyser was used to estimate the CO,CO_2,NO_x,HC emissions .Here the NO_X and HC emission was measured in ppm while CO_2,CO in percentage. The emissions for pure gasoline and the selected gasoline MTBE blends were observed at various speeds.

VII. EXPERIMENTAL OBSERVATIONS

Tests for pure gasoline and MTBE blended gasoline (M5, M10) were conducted and BSFC and BTE were calculated at various speeds to give an idea about the engine performance.

7.i BSFC vs SPEED

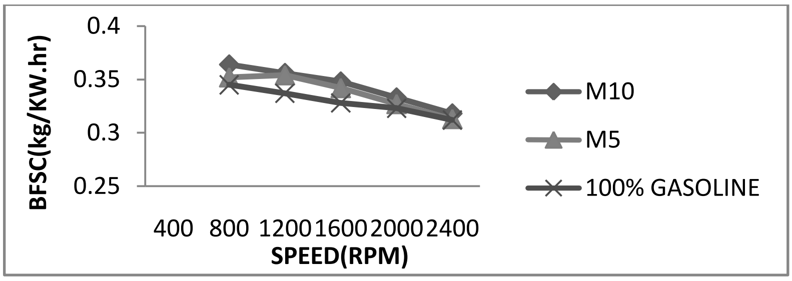

Figure 2

The BSFC is an indicator for the efficiency of fuel . It is calculated by the formula:

BSFC= FUEL CONSUMPTION RATE / POWER REQUIRED

The BSFC was calculated in kg/KWhr and was plotted versus engine speed. It was observed that BSFC decreased with speed. This is due to the fact that the power produced is more at higher speeds. There was an increase in BSFC with the addition of MTBE compared to pure gasoline. The calorific value of MTBE (35.1 MW/kg) is lower compared to that of gasoline (42MW/kg).This leads to an increase in fuel consumption rate. Lower viscosity and volatility are also factors having a role in BSFC characteristics. The peak value of BSFC was achieved with M10 as 0.364 kg/KW-hr at 800 rpm which was higher than the of pure gasoline ,whose BSFC value was 0.345 kg/KW-hr at the same engine speed.

7.ii BTE vs SPEED

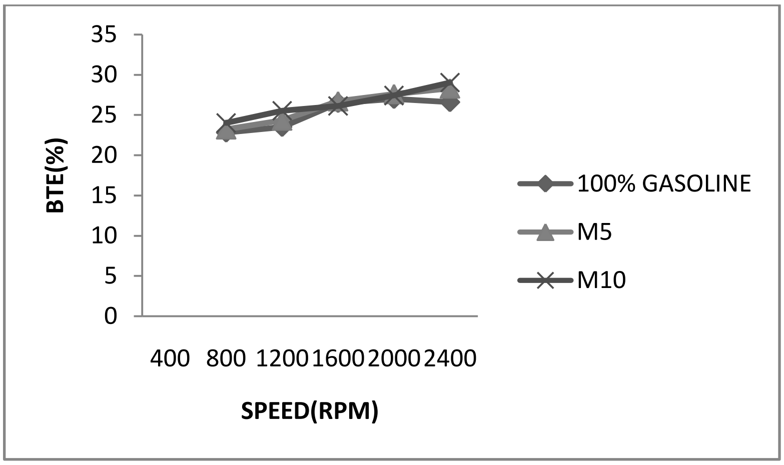

Figure 3

The brake thermal efficiency gives a view about the capacity to convert the chemical energy of the fuel to the required thermal energy The brake thermal efficiency of the engine was estimated for the MTBE-gasoline blends and pure gasoline at various speeds were plotted in fig.5.It was noted that the BTE increased with engine speed . This elevation in efficiency due to complete combustion of gasoline at high engine speeds. M10 and M5 had higher BTE compared to pure gasoline. The higher octane number of MTBE compared to gasoline and more complete ignition is the reason for the higher efficiency. The maximum efficiency of pure gasoline and the blends were achieved at 2400 rpm, an increase in efficiency of 2.4% was noticed on the use of M10 as opposed to the use of pure gasoline.

7.iii CO vs SPEED

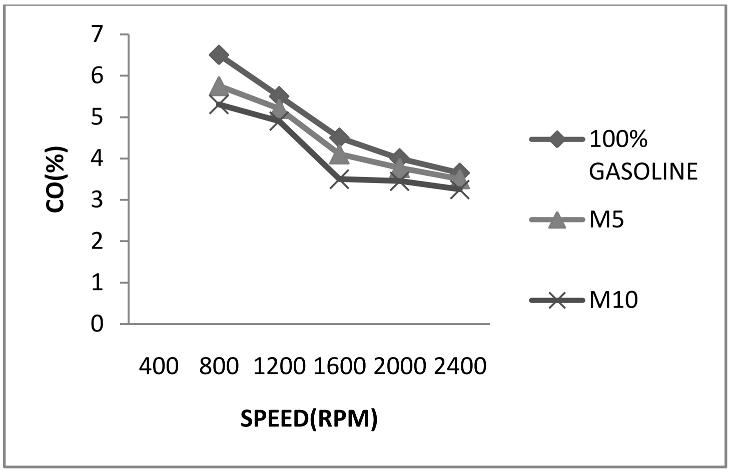

Figure 4

The fig. 4 showed the characteristics of CO emission versus speed of pure gasoline and MTBE blended gasoline .It was observed that the emission decreased with blending of MTBE.

CO(Carbon Monoxide) is a colorless, poisonous gas. It is produced due to incomplete oxidation of carbon in gasoline.

CO is less stable compared to CO_2 due to the presence of carbon oxygen triple bond. Hence, the standard enthalpy of formation of carbon monoxide is less compared to carbondioxide. The CO emission was observed to decrease with speed and blending with MTBE. Lack of oxygen leads to carbon oxidising to monoxide . The CO emission reduced due to the oxygen content present in MTBE . Carbon gets oxidised to CO_2 during complete combustion but in incomplete combustion it gets converted to l CO. CO emission reduced with the increase in speed as at higher speeds there was more CO_2 emission .The CO emission at 2400 rpm was reduced from 3.65% by using gasoline to 3.25% on the use of M10.There was a reduction in content of CO was more visible at lower speeds.

7.iv CO_2 vs SPEED

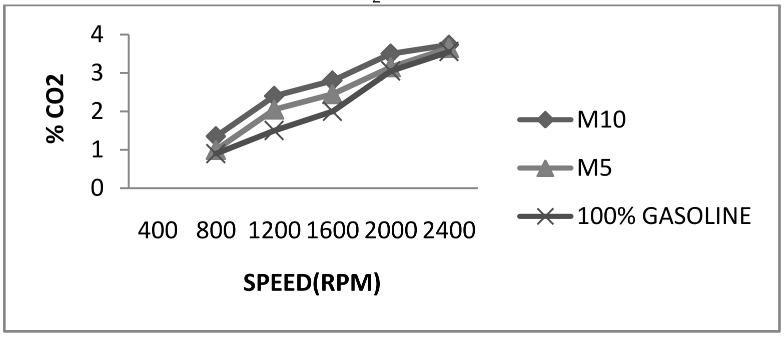

Figure 5

Fig.5 is the plot of CO_2 with speed. CO_2 emission increased with speed in case of pure gasoline and gasoline blended MTBE. CO_2 is a product of complete oxidation of carbon in gasoline. Reaction rate increases on attaining higher speeds This increased reactivity favours complete combustion. Hence, the formation of dioxide is more favourable compared to monoxide. The CO_2 emission was also observed to increment on using M5 and M10 compared to pure gasoline.
The greater percentage of CO_2 in M10 blend indicates the complete combustion.
The main reason for the formation of carbon monoxide is the dearth of oxygen for oxidation in the combustion process. Having oxygen content, the addition of MTBE encourages the formation of CO_2 rather CO. The presence of oxygen atom in MTBE favours the complete oxidation of carbon to dioxide rather than incomplete oxidation to monoxide. The maximum emission of CO_2 was observed in M10 at 2400 rpm as 3.73 % compared to 3.55% on the use of pure gasoline.

7.v NO_X vs SPEED

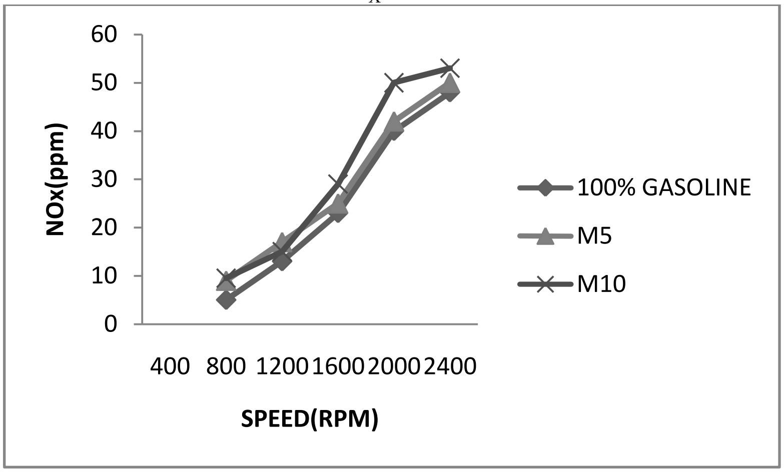

Figure 6

The impact of blending on NO_X emission is clearly seen in fig.6. NO_X refers to the content of oxides of nitrogen in flue gas. Oxygen and nitrogen don't react at room temperatures, but nitrogen oxidizes at high temperature. The temperature in combustion chamber makes this reaction feasible.

The NO_x emissions are minimal at low speeds and are found to increase with speed. At higher speeds the operation temperature increases paving way for more NO_x formation. At 800 rpm the NO_x content was in the range of 5ppm to 9.5ppm, while at 2400 rpm it was in the range from 48ppm to 53ppm .There was an observed increase in emission of NO_x among M5 and M10 compared to pure gasoline . This was primarily due to the higher content of energy released during complete combustion of fuel. This in turn leads to elevated operating temperature and subsequently more NO_x emission.

7.vi HYDROCARBON vs SPEED

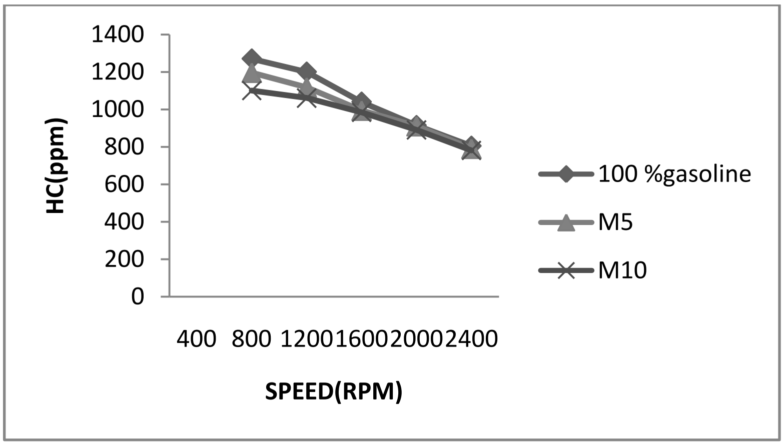

Figure 7

The HC emission was measured in parts per million parts (ppm). The emission of HC gives an idea about the of the quality of air-fuel mixture and the completeness of combustion. H_2O and CO_2 are the only products obtained in 100% combustion of gasoline. However, in case of incomplete combustion there is a presence of un-burnt hydrocarbons. Thus residual HC is a measure of inefficiency of combustion process .The HC emission was found to decrease with speed. At elevated engine speed the rate of reaction increases and the tendency for incomplete combustion declines thereby reducing HC emissions. Also there is a fall in HC emission with blending. Complete combustion on the use of MTBE was the reason behind the fall in HC levels .Significant decline in HC emission was noted on the use M10 compared to pure gasoline as the fuel. HC emissions reduced from 805 ppm for pure gasoline to 780ppm for M10 , difference in emission being a mere 25 ppm at 2400 rpm. While at 800 rpm the emission values were 1270ppm and 1100ppm, difference in emission rates being 160ppm. Hence, there is an decline in the influence of additives with increase in engine speed. This is due to the reduction in residual hydrocarbon at higher speeds .

VIII. INFERENCE

- Addition of MTBE leads to the increase of BSFC and BTE. Hence blending indicating better performance.
- Due to complete combustion of fuel and presence of oxygen there was a reduction in CO and HC emissions. The CO and HC emission reduces with the increase in engine speed. The CO and HC emission is reduced by complete combustion where more CO is converted to CO2and Hydrocarbon was also converted to water and Carbon-dioxide during the usage of blended fuel. Hence the dioxide content increased. Also, the NO_x also increased appreciably with speed .Blending also resulted in higher NO_X emissions due to the oxygen content in MTBE.
- The emission characteristics indicates more efficient combustion of blends(M5, M10) compared to pure gasoline

REFERENCES

[1] Lennox Siwale, Lukács Kristóf, Akos Bereczky, Makame Mbarawa, Andrei Kolesnikov, Performance, combustion and emission characteristics of n-butanol additive in methanol–gasoline blend fired in a naturally-aspirated spark ignition engine, Fuel Processing Technology, Volume118, February 2014, Pages 318-326

[2] Mohsen Ghazikhani, Mohammad Hatami, Behrouz Safari, Davood Domiri Ganji, Experimental investigation of performance improving and emissions reducing in a two stroke SI engine by using ethanoladditives, Propulsion and Power Research, Volume 2, Issue 4, December 2013, Pages 276-283

[3] Shen Yu Wang, Zhen Wang, Ming Ming Liu, Yu Xu, Xiao Jun Zhang, Guo-Qiang Chen, Properties of a new gasoline oxygenate blend component: 3-Hydroxybutyrate methyl ester produced from bacterial poly-3-hydroxybutyrate, Biomass and Bioenergy, Volume 34, Issue 8, August 2010, Pages 1216-1222

[4] Soheil Babazadeh Shayan, Seyed Morteza Seyedpour, Fathollah Ommi, Effect of oxygenates blending with gasoline to improve fuel properties, Chinese Journal of Mechanical Engineering,July 2012, Volume 25, Issue 4, pp 792-797

[5] G.A. Westphal, J. Krahl, T. Brüning, E. Hallier, J. Bünger, Ether oxygenate

additives in gasoline reduce toxicity of exhausts, Toxicology, Volume 268, Issue 3, 9 February 2010, Pages 198-203

[6] Sara Safari Kish, Alimorad Rashidi, Hamid Reza Aghabozorg, Leila Moradi, Increasing the octane number of gasoline using functionalized carbon nanotubes , Applied Surface Science, Volume 256, Issue 11, 15 March 2010, Pages 3472-3477

[7] Dale Turner, Hongming Xu, Roger F. Cracknell, Vinod Natarajan, Xiangdong Chen, Combustion performance of bio-ethanol at various blend ratios in a gasoline direct injection engine , Fuel, Volume 90, Issue 5, May 2011, Pages 1999-2006

[8] Shakeel Ahmed, Mohamed Z. El-Faer, Mohamed M. Abdillahi, Mohamed M. Abdillahi, Mohammed A.B. Siddiqui, Sami A.I. Barri, Production of methyl tert-butyl ether (MTBE) over MFI-type zeolites synthesized by the rapid crystallization method and modified by varying Si/Ai ratio and steaming, *Applied Catalysis A: General*, *Volume 161, Issues 1–2*, *4 November 1997*, *Pages 47-58*

[9] Renato Cataluña, Dícles Dalávia, Rosângela da Silva, Eliana Menezes, Vanessa Venturi, Rafael Wagner, Acceleration tests using gasolines formulated with di-TAE, TAEE and MTBE ethers, Fuel,Volume 90, Issue 3, March 2011, Pages 992–996

[10] I. Gravalos, , D. Moshou, Th. Gialamas, P. Xyradakis, D. Kateris, Z. Tsiropoulos Emissions characteristics of spark ignition engine operating on pure and high alcohol blended gasoline fuels, Renewable Energy, Volume 50, February 2013, Pages 27–32

[11] Bang-Quan He, Jian-Xin Wang, Ji-Ming Hao, Xiao-Guang Yan, Jian-Hua Xiao, A study on emission characteristics of an EFI engine with ethanol blended gasoline fuels, Atmospheric Environment, Volume 37, Issue 7, March 2003, Pages 949-957

[12] Rosângela da Silva, , Renato Cataluña, Eliana Weber de. Menezes, Dimitrios Samios, Clarisse M. Sartori Piatnicki, Effect of additives on the antiknock properties and Reid vapor pressure of gasoline, Fuel, Volume 84, Issues 7–8, May 2005, Pages 951–959

[13] Chong-Lin Song, Wen-Mei Zhang, Yi-Qiang Pei, Guo-Liang Fan, Guan-Peng Xu, Comparative effects of MTBE and ethanol additions into gasoline on exhaust emissions, Atmospheric Environment, Volume 40, Issue 11, April 2006, Pages 1957-1970

[14] Jian Gao, Deming Jiang, Zuohua Huang, Spray properties of alternative fuels: A comparative analysis of ethanol–gasoline blends and gasoline, Volume 86, Iss uly–August 2007, Pages 1645-1650ues 10–11, July–August 2007, Pages 1645-1650